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Analysis of Dump-Point Accidents Involving Mobile Mining Equipment

By J. P. May

DEPARTMENT OF THE INTERIOR
U.S. ★ BUREAU OF MINES ★
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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ft	foot	pct	percent
lb	pound	st	short ton

ANALYSIS OF DUMP-POINT ACCIDENTS INVOLVING MOBILE MINING EQUIPMENT

By J. P. May[1]

ABSTRACT

This U.S. Bureau of Mines report identifies and evaluates factors responsible for dump-point accidents involving mobile mining equipment. Information regarding the occurrence and severity of the accidents, the industries affected, the types of equipment involved, the primary and contributing causes, and pertinent Federal regulations is included. The aim of this report is to provide information that will aid mine operators in the recognition of hazards associated with mobile equipment operation near the dump points of stockpiles and waste dumps.

[1]Mining engineer, Twin Cities Research Center, U.S. Bureau of Mines, Minneapolis, MN.

INTRODUCTION

Dump-point accidents occur in all of the major mineral industries including coal, metal, nonmetal, crushed stone, and sand and gravel. These industries, either through the construction of temporary material stockpiles or construction of semipermanent to permanent waste or spoil piles, utilize large mobile mining equipment in elevated areas near dump points. Almost without exception, the dump-point accident involves the fall of such equipment over the edge and down the front slope of the stockpile or waste dump. The types of mining equipment involved in these stockpile accidents include front-end loaders, dozers, scrapers, and various sizes of haulage trucks from 20-st-capacity units for highway use to 170-st-capacity mine haulage trucks (dumpers) designed for off-highway use.

Accidents involving dump points were analyzed for the 1983-87 period. It was felt that a 5-year period would be large enough to present a representative sample of accidents, yet would keep the amount of data at a level that could be reasonably managed. The most recent 5-year period for which data were available was chosen to provide the best representation of current mining methods and technology.

All data utilized in the analysis were gathered from an accident data base maintained by the Bureau. The computerized data base, known as ADA (accident data analysis), is based on accident and injury report data files gathered by the Safety and Health Technology Center (SHTC) in Denver, CO, a branch of the Mine Safety and Health Administration (MSHA). These data files include all coal and metal-nonmetal accidents reported by mining operations dating back to the early 1970's.

A mine operator is required to submit a report for each accident or occupational injury meeting the criteria in title 30, part 50, of the Code of Federal Regulations (CFR). Based on accident severity, the operator may also be required to contact MSHA immediately. MSHA officials will make a determination if a more thorough investigation is necessary. By MSHA's definition of an accident and occupational injury, reporting is only required for those dump-point accidents that caused death or that had a reasonable potential to cause death, that resulted in lost work time, that required medical treatment, or that restricted an individual from performing his or her normal duties.

For the purpose of the analysis in this report, only those accidents that met MSHA reporting criteria were studied, not all dump-point accidents that occurred. In addition to SHTC narratives, original mine reports and any available investigation reports for each specific accident were obtained. All information gathered was reviewed by three project members. The data were then organized and classified, providing the structure for the analysis of accidents in this report.

This report is organized into two primary sections. The first section analyzes the effect of dump-point accidents on the mining industry. The second section provides a detailed analysis of dump-point accidents for each equipment type. The majority of the second section emphasizes haulage trucks and includes a less descriptive and more generalized analysis for front-end loaders, dozers, and scrapers. A review and discussion of MSHA regulations pertaining to dump-point safety is also provided.

DEFINITIONS

The following are definitions of selected terms used in this report:

Berm.–A pile or mound of material used to prevent travel of mobile mining equipment over the edge of a bank; normally used along the edge of haulroads and the crests of stockpiles.

Dump Point.–The active area of a stockpile, waste dump, or spoil pile where material is placed during construction of the pile; normally at the edge or crest of the pile.

Haulage Truck.–Self-propelled wheeled machine, having an open body, which transports and dumps or spreads material. Loading is performed by means external to the truck. The term "haulage truck" is used in lieu of the International Organization for Standardization (ISO) term "dumper" because haulage truck is a more familiar term to U.S. mining industries.

Lost-Workday Accident (LWA).–Injury resulting in the inability to perform all job duties on any day after the injury.

Mobile Mining Equipment.–Tracked or rubber-tired equipment which by its nature is mobile. For the purpose of this report it means earth-moving equipment used around surface stockpiles; specifically, haulage trucks, front-end loaders, dozers, and scrapers.

MSHA.–Mine Safety and Health Administration, regulatory and enforcement branch of the U.S. Department of Labor responsible for maintenance of mine safety through enforcement of Federal mine laws and technical and training assistance to mine operations.

Spoil Pile.–A structure consisting of unconsolidated overburden materials removed during surface coal mining operations.

Stockpile.–An accumulation of ore or mineral formed to create a reserve to feed a processing plant or for direct shipment.

Surge Pile.–Similar to a stockpile only usually smaller and more temporary in nature.

Waste Dump.–A mine waste structure or dump. An accumulation of non-ore-bearing waste material removed for development of an ore body.

SCOPE OF PROBLEM

The purpose of this section is to develop an understanding of the impact of dump-point accidents on the mining industry. The scope of the problem will be brought into perspective through analysis and comparison of progressively narrowing accident categories, eventually focusing on the subcategory of dump-point accidents. This will be accomplished through the comparison of the frequency and severity of all surface mining accidents,[2] all surface mobile mining equipment accidents, and finally all dump-point accidents. A breakdown of dump-point accidents by equipment type will also be provided.

SURFACE MOBILE MINING EQUIPMENT ACCIDENTS AS A PERCENTAGE OF ALL SURFACE MINING ACCIDENTS

Surface mobile mining equipment accidents are more severe than the average surface mining accident and are responsible for a disproportionate share of the total fatalities and lost workdays. Table 1 provides a summary tabulation of accident data for all surface-mining-related accidents for the 1983-87 period. It also shows the frequency of accidents involving surface mining mobile equipment and those involving mobile equipment at dump points. A comparison of mobile mining equipment accidents as a percentage of all surface-mining-related accidents, and a comparison of dump-point accidents as a percentage of all mobile mining equipment accidents is also provided.

The potential for an accident resulting in a serious injury is greater for the operator of a piece of mobile mining equipment than the average surface miner. While mobile mining equipment accidents are only responsible for 8 pct of the total surface accidents they result in 27 pct of the fatalities and 11 pct of the total lost workdays. This can be attributed to the size and complexity of the equipment involved and the ever changing mine environment. The mine environment changes to reflect the natural progression of development that occurs in a mining operation as well as the effect of external factors such as weather. In addition many of the older mining operations, which were originally designed for small equipment, have updated to larger equipment without corresponding changes in mine layout and facilities.

Safe operation of mobile equipment is extremely dependent on the capabilities of the operator. The ability of an operator to identify and react correctly and quickly to a potential hazard that may develop is more critical for mobile equipment operation than for most mining tasks. The dynamic environment of mobile equipment operation and nature of the job thus provide a greater potential for a hazardous situation to develop and a serious injury to occur.

DUMP-POINT ACCIDENTS AS A PERCENTAGE OF SURFACE MOBILE MINING EQUIPMENT ACCIDENTS

Accidents involving the operation of mobile equipment near the dump point of stockpiles and waste dumps are significant in their impact on the total number of fatalities and lost workdays experienced by mobile equipment operators (table 1).

A dump-point accident is more severe in nature than an average mobile equipment accident. A dump-point LWA results in an average loss of 67.0 days from work versus an average loss of 36.9 days from work for all other surface mobile mining equipment accidents, and is responsible for a disproportionate share of the fatalities. The severity of dump-point accidents can be attributed to the extreme nature of an accident where a large piece of mobile equipment falls over a high embankment. More specific parameters relating to dump-point accidents will be discussed in the "Primary Accident Causes" section.

[2]For this report, surface mining accidents include all those accidents categorized by MSHA as surface at underground, strip-open pit, surface auger, culm bank-refuse, dredge mining, and other surface. They do not include accidents categorized by MSHA as underground, independent shops-yards, preparation plants, and offices.

Table 1.–Surface mining, surface mobile mining equipment, and dump-point accident data, 1983-87[1]

Category	Accidents	Fatalities	Lost-workday accidents	Lost workdays
All surface	35,042	252	21,162	646,758
Mobile equipment:				
Total	2,805	67	1,845	70,522
Portion of all surface ... pct	8	27	9	11
Dump point:				
Total	103	11	72	4,821
Portion of mobile equipment ... pct	4	16	4	7

[1]Mobile equipment and dump-point accidents were not considered in the surface category; dump-point accidents were not considered in the mobile equipment category.

SUMMARY OF PROBLEM

Accidents involving the operation of mobile equipment near the dump point of stockpiles and waste dumps account for 0.3 pct of all surface-mining-related accidents.

Although the frequency of reportable dump-point accidents is relatively low, the severity of the accidents is high, resulting in a substantial impact on the mining industry. Of the dump-point accidents reported to MSHA, 10.7 pct resulted in a fatality compared to only 2.1 pct for mobile-equipment-related accidents and 0.57 pct for all other surface-mining-related accidents. This high frequency rate resulted in dump-point accidents being responsible for 4.37 pct of all surface-mining-related fatalities, which is a significant percentage of the total. The severity of dump-point accidents is also reflected in the average number of days off for each LWA. Each dump-point LWA results in an average of 67.0 days lost from work. This compares to an average of only 36.9 days for mobile-equipment-related accidents and 29.8 days for all other surface-mining-related accidents.

FREQUENCY AND SEVERITY OF DUMP-POINT ACCIDENTS, BY EQUIPMENT TYPE

Haulage trucks were responsible for 80 pct of all the dump-point accidents that occurred in the 5-year period studied. A breakdown on the percentage of dump-point accidents by equipment type is shown in figure 1. As would be expected, haulage trucks are also responsible for a significant majority of both the total fatalities and the total lost workdays experienced. This is demonstrated in figure 2 where the percentage of dump-point fatalities and lost workdays is given by equipment type.

Haulage trucks show a slightly lower frequency of fatalities and higher percentage of lost workdays than the percentage of total accidents would indicate. Conversely dozers and front-end loaders show a higher frequency of fatalities and lower percentage of lost workdays than the percentage of total accidents would indicate. This would indicate that although infrequent, dozer and front-end loader dump-point accidents involving a fall down a slope have a lower potential for operator survivability than haulage truck or scraper accidents. Scraper dump-point accidents, although extremely infrequent, do demonstrate a high degree of severity. Although no fatalities were recorded, they did result in 8.0 pct of the total lost workdays. A summary of dump-point accident data by mobile equipment type is provided in table 2.

The remainder of this report will emphasize the causes of dump-point accidents and specific parameters affecting their occurrence. From the preceding discussion and a review of table 2, it is obvious that the primary impact on the mining industry results from dump-point accidents involving haulage trucks. For this reason, the majority of the remainder of this report will emphasize dump-point accidents involving haulage trucks. A final brief discussion of accidents involving front-end loaders, dozers, and scrapers will then follow.

Table 2.–Dump-point accident data by equipment type, 1983-87

Equipment	Accidents	Fatalities	Lost-workday accidents	Lost workdays
Haulage trucks	82	7	61	4,282
Front-end loaders	6	2	1	15
Dozers	11	2	7	140
Scrapers	4	0	3	384

ANALYSIS OF DUMP-POINT ACCIDENTS INVOLVING HAULAGE TRUCKS

GENERAL

The ADA data base contained 82 dump-point accident narratives involving haulage trucks for the 1983-87 period. All original reports pertaining to the 82 accidents were reviewed. Two types of reports were available, full investigative accident reports prepared by MSHA personnel and one-page MSHA Report Form 7000-1–Mine Accident, Injury, and Illness reports completed and sent to MSHA by mine operators pursuant 30 CFR 50. These reports were requested to supplement data acquired through the ADA data base. The full investigative reports provided detailed information about the accidents, the causes of the accidents, and recommended procedures to be taken to prevent their recurrence. These full investigative reports were extremely beneficial in analysis of the dump-point accidents, however, they were only available for 26 of the accidents or 32 pct of the total. The remaining 56 accidents could only be analyzed by use of the one-page 7000-1 forms, which often did not provide enough data to identify accurately the causes of the accidents.

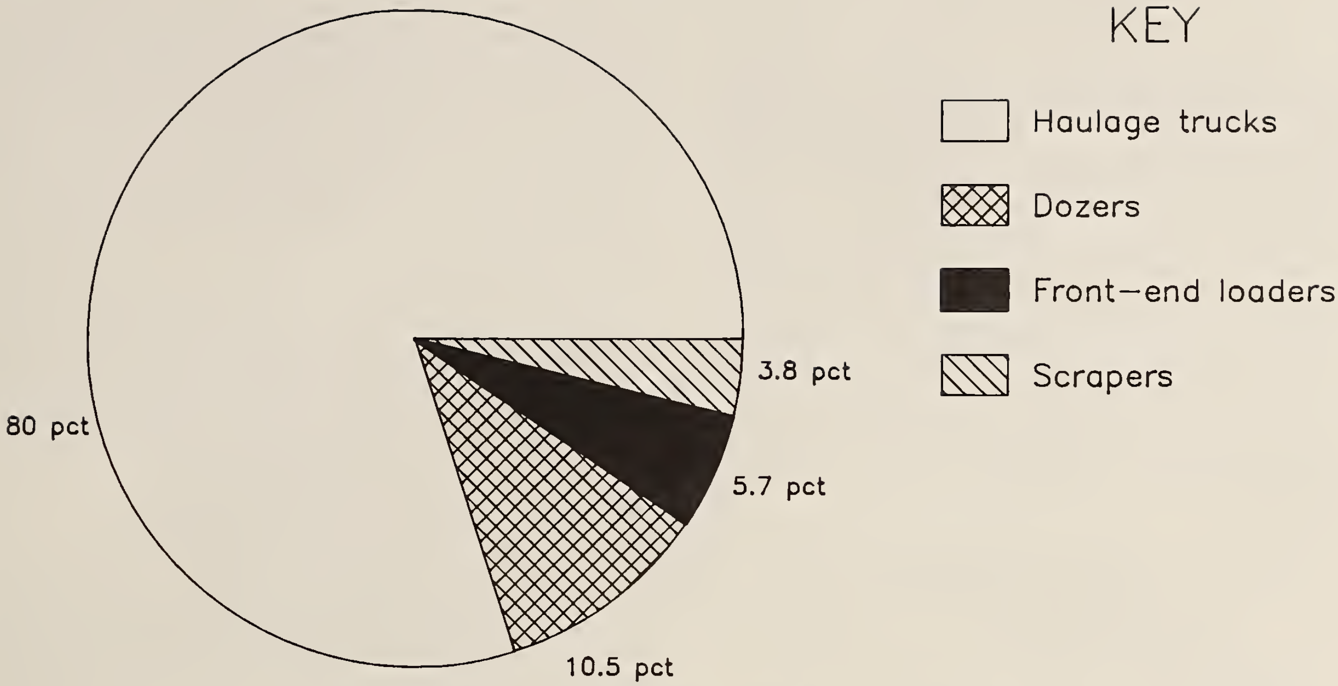

Figure 1.–Percentage of dump-point accidents by equipment type.

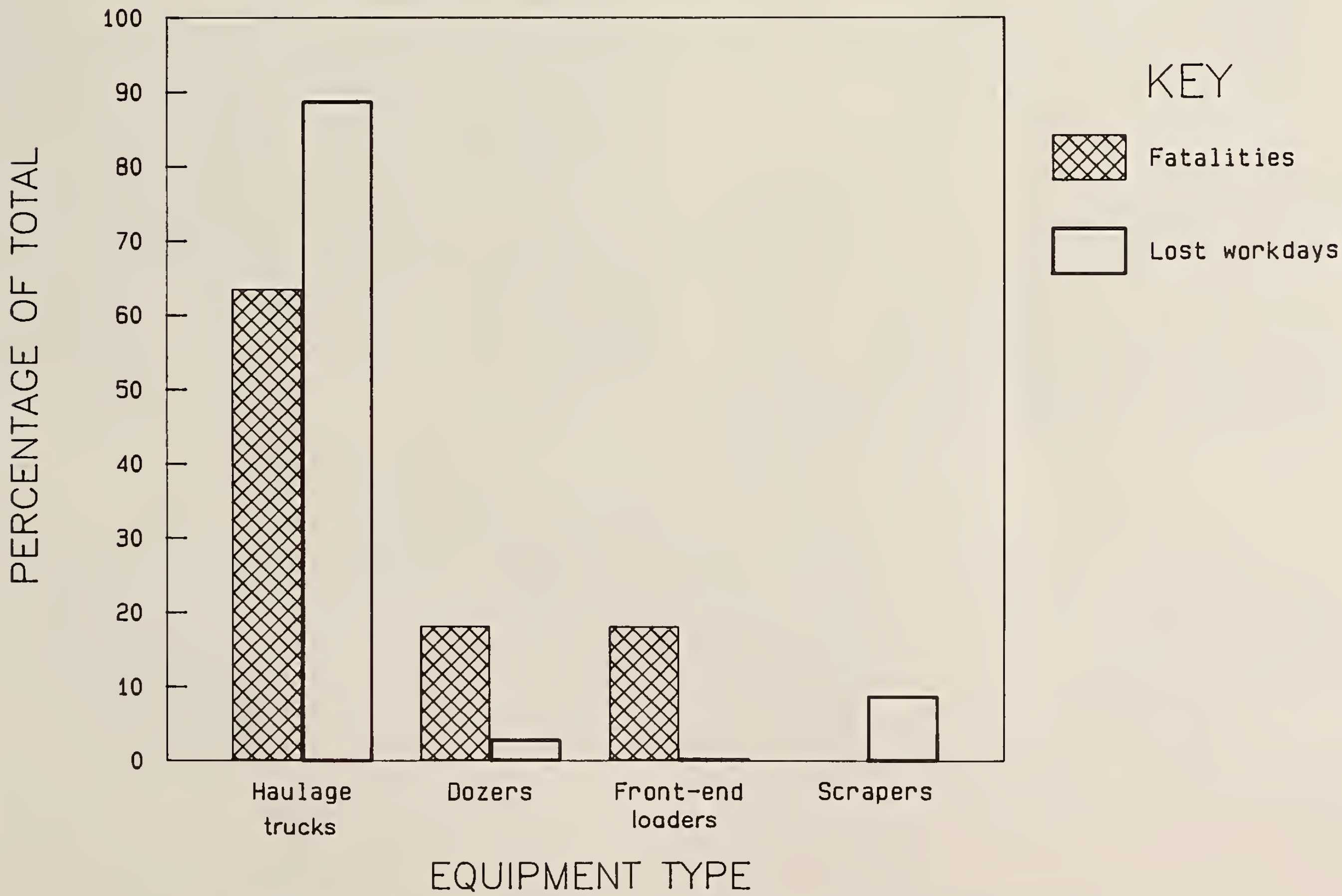

Figure 2.–Percentage of dump-point fatalities and lost workdays by equipment type.

Industry Affected

A percentage breakdown of dump-point accidents by mineral industry is provided in figure 3. Combining sand and gravel operations and crushed stone operations, aggregate producers as a group are responsible for 55 pct of all accidents. The remaining dump-point accidents predominantly occurred in the coal industry.

Table 3 provides a breakdown of dump-point accidents by specific commodity for each mineral industry. The occurrence of the majority of dump-point accidents within a few mineral industries and specific commodities is significant. It suggests that certain material parameters or procedural activities occur in the crushed stone and coal industries that do not occur with frequency in the other mineral industries. Identification of these differences will aid in development of methods to reduce dump-point accidents.

Table 3.–Dump-point accidents involving a haulage truck, by commodity

Industry and commodity	*Accidents*
Crushed stone:	
Limestone	25
Granite	4
Traprock	4
Miscellaneous stone	4
Caliche	1
Coal: Bituminous	25
Metal:	
Copper	3
Gold	2
Iron	1
Lead	1
Silver	1
Sand and gravel	7
Other:	
Milled products: Cement	2
Nonmetal:	
Clay	1
Talc	1

Dump-Point Structures

Table 4 lists the number of dump-point accidents by industry and type of structure involved (see "Definitions" section). It was possible to determine the type of structure involved in 84 pct of the dump-point accidents analyzed. In metal-nonmetal mining operations, stockpiling activities accounted for the majority of dump-point accidents, with 53 pct of the known total. This highlights the potential hazards of temporary structures that by their nature have a high amount of mobile equipment activity; this activity occurring at the top of the pile where dumping takes place and at the toe of the pile where some sort of loading procedure takes place.

Crushed stone stockpiles were responsible for the single greatest amount of accidents–32 pct of the total. This results from the large amount of stockpiling activity associated with crushed stone operations. In the coal industry, waste dumps and spoil piles were responsible for the greatest percentage of accidents, whereas stockpile-associated accidents only occurred twice.

Dump-Point Construction Materials

Specific material parameters were not available for the dump-point structures, however, generalized categories of construction materials could be determined (table 5). Of the 52 accidents in which it was possible to determine the dump-point material, overburden, mine run (blasted stone), and screened stone were involved in the most accidents.

Overburden was involved in the majority of the known cases (30 pct) and in both coal and metal-nonmetal mining operations. Overburden consistency can vary widely from location to location and can be an unpredictable material. Overburden is normally associated with permanent waste structures such as waste dumps or spoil piles.

Mine run rock or blasted rock awaiting crushing was involved in 19 pct of the known cases, and occurred exclusively in metal-nonmetal mining operations. Screened stone was involved in 17 pct of the known cases and occurred exclusively in the crushed stone or aggregate industry. Both mine run rock and crushed stone are associated with stockpile structures. The remainder of the known materials are distributed as shown in table 5.

Table 4.–Structures involved in dump-point accidents, 1983-87

Industry	Stockpile	Waste dump	Surge pile	Spoil pile	Other	Unknown	Total
Crushed stone	26	6	3	0	0	3	38
Coal	2	6	0	7	4	6	25
Metal	3	2	0	0	1	2	8
Sand and gravel	4	1	0	0	0	2	7
Other	1	3	0	0	0	0	4
Total	36	18	3	7	5	13	82

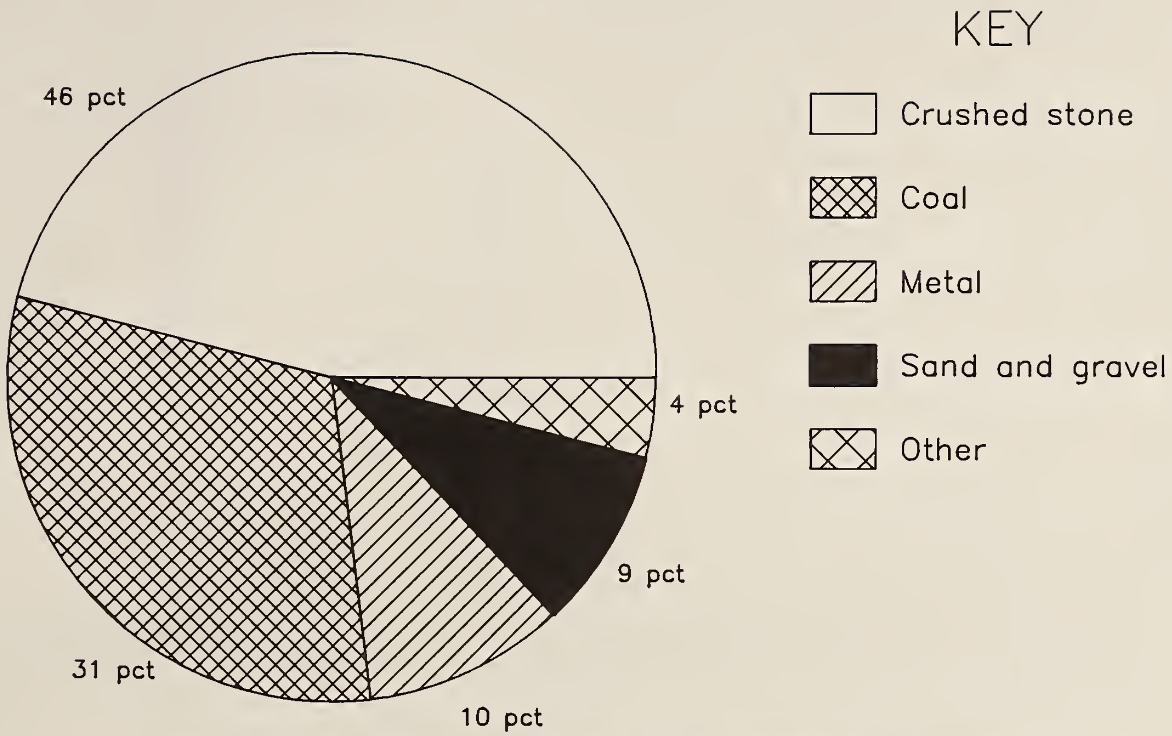

Figure 3.–Percentage of dump-point accidents involving a haulage truck, by industry.

Table 5.–Dump-point construction materials involved in haulage truck accidents, by industry

Material	Coal	Metal-nonmetal
Unknown	10	20
Overburden	11	5
Mine run	0	10
Screened stone	0	9
Waste rock	3	3
Fines, dust	0	3
Sand	0	3
Lime	0	2
Coal	1	0
Gravel	0	1
Green shale	0	1
Total	25	57

Equipment Specifications

The distribution of haulage trucks involved in dump-point accidents is shown in figure 4, by capacity. As can be seen, the majority of the dump-point accidents involved relatively smaller haul units in the 20- to 85-st-capacity range. It is felt (although unconfirmed) that this size distribution would correlate closely to the average haulage truck size distributions found in the industries analyzed.

OPERATOR-RELATED FACTORS

Age

The age of operators involved in dump-point accidents varied from 19 to 62. The percentage of total dump-point accidents by age group is shown in figure 5. The line with the star markers represents the age of operators involved in the dump-point accidents.

The age distribution of operators involved in dump-point accidents closely matches the normal age distribution for mine truck drivers. It therefore appears that there is no relationship between the age of a haulage truck operator and the potential that he or she will be involved in a dump-point accident.

Job Experience

A significant portion of dump-point accidents involve operators with very little to no experience operating a haulage truck. The number of dump-point accidents involving a haulage truck by years of job experience is shown in figure 6.

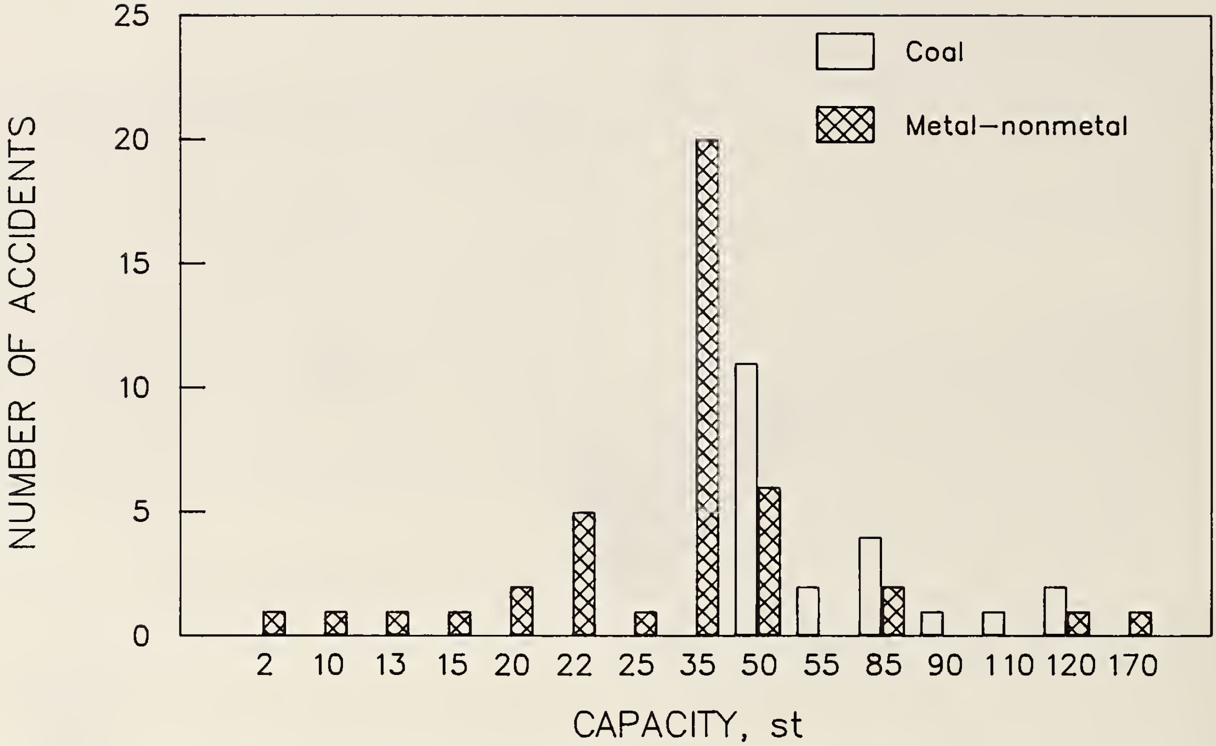

Figure 4.–Number of haulage trucks involved in dump-point accidents, by capacity.

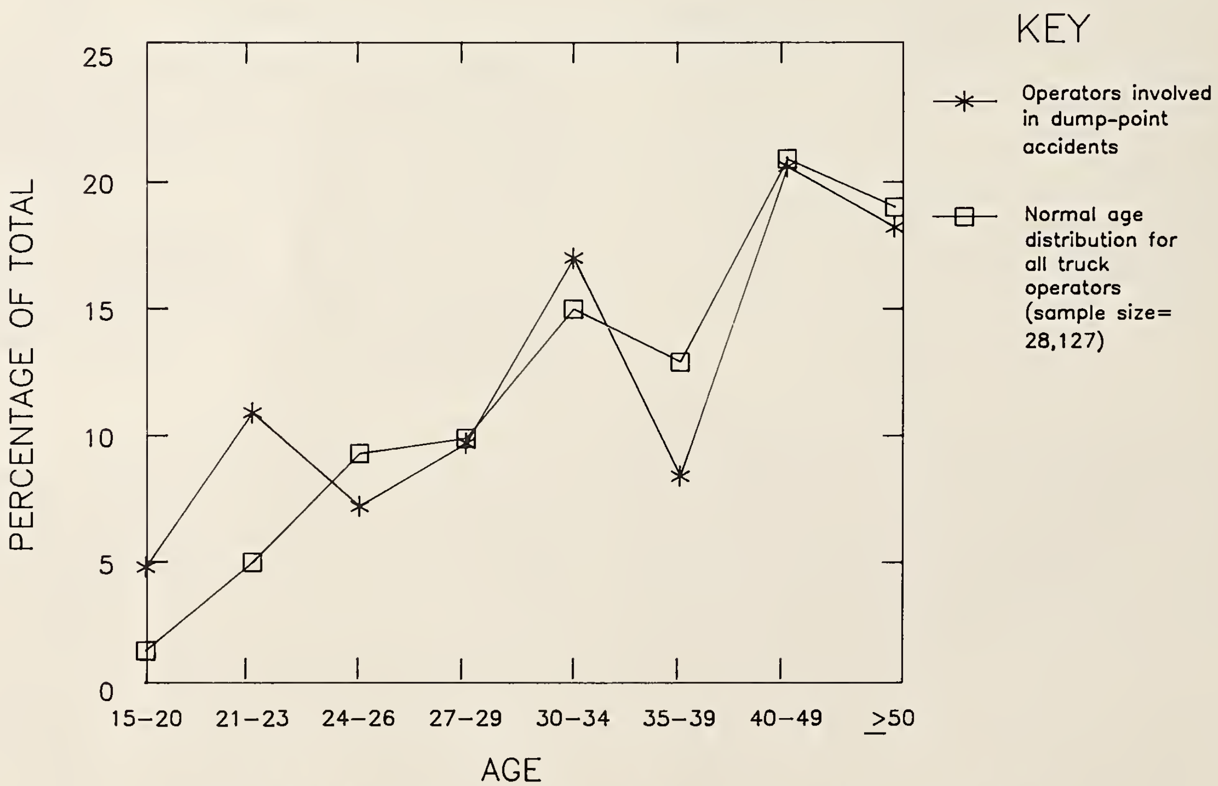

Figure 5.–Percentage of total dump-point accidents involving a haulage truck, by age group.

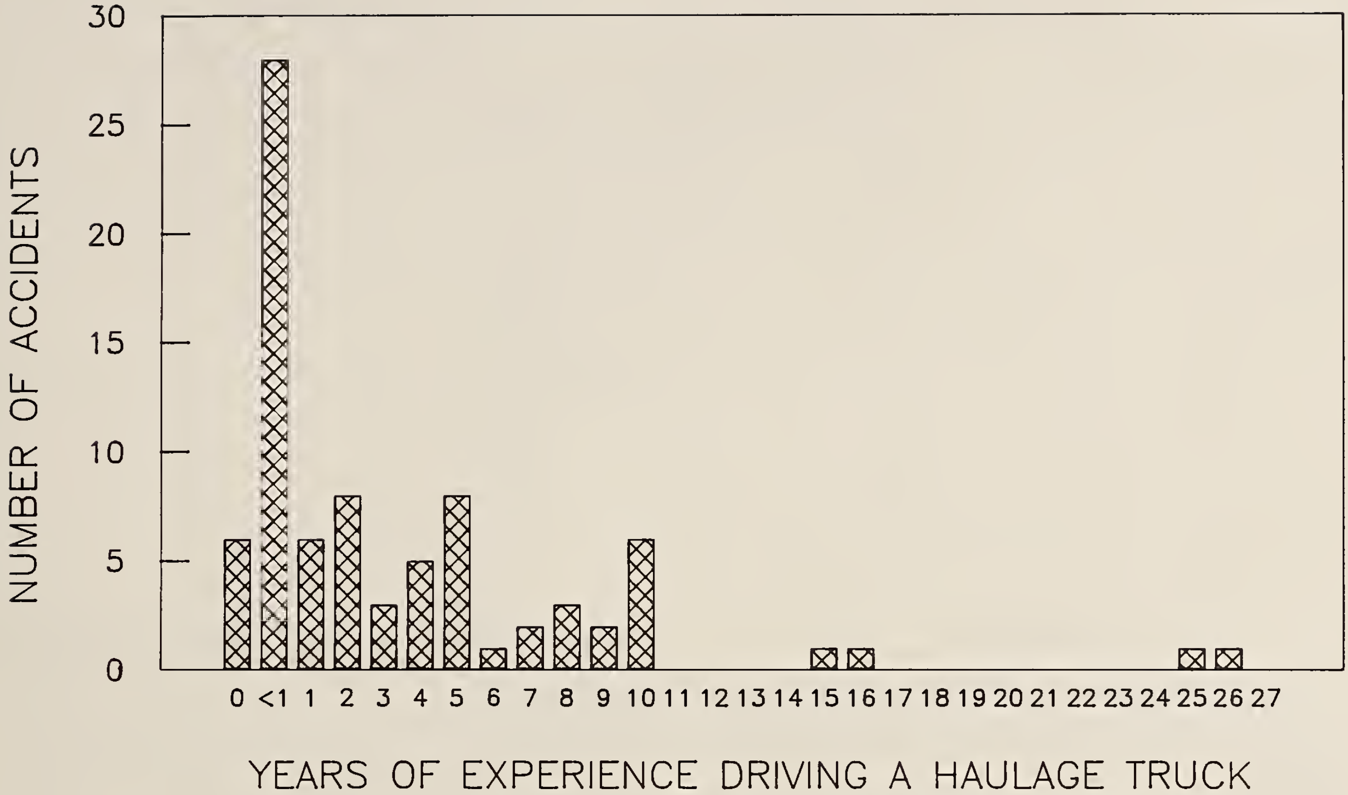

Figure 6.–Number of dump-point accidents involving a haulage truck, by years of job experience.

The average amount of job experience for a haulage truck operator involved in a dump-point accident is 3.81 years. However, 41 pct of all dump-point accidents occurred to an operator with less than 1 year of haulage truck experience. Of those accidents involving less than 1 year of experience, 41 pct had less than 1 month experience and 82 pct had less than 6 months of experience.

It is obvious that lack of job experience is a significant contributing factor to the occurrence of a dump-point accident. This suggests that experienced operators have learned to identify and avoid potentially unsafe areas for dumping or have learned operating techniques that tend to prevent dump-point accidents. Increased emphasis on hazards associated with stockpiles and waste dumps during mandatory miner training would have a significant impact on the reduction of dump-point accidents. The fact that inexperience is a major contributing factor suggests that human error (administrative and operator) is responsible for a majority of the accidents.

Mine Experience

The number of accidents per year of total mine experience is shown in table 6. The average amount of total mine experience for an operator involved in a dump-point accident is 7.3 years or 3.5 years higher than the average specific job experience. This suggests that experience gained in mining activities other than driving a haulage truck has little impact on the operator's ability to safely operate a haulage truck when he or she is eventually assigned to that task. This could also imply a supervisor's incorrect assumption that an experienced miner has the required training or experience to perform a new task even when he or she has not performed that specific task.

Drug and Alcohol Abuse

Drug testing is rarely performed in the mining industry after an accident has occurred. The exception to this is when an autopsy is performed after a fatal accident. Of the 82 haulage truck accidents reviewed in this study, only five reports made mention of drugs or alcohol. Two of these reports specifically stated that drugs were not a contributing factor. Therefore, only three accidents occurred where drugs could be considered as a contributing factor and two of these involved fatalities. Although the use of drugs and alcohol is often mentioned as a potential contributing factor in accidents, there is very little evidence to substantiate this for dump-point accidents. The fact that two of the seven fatalities involved alcohol could indicate the potential for a more serious accident to occur while under the influence or just that more thorough testing is performed when a fatality occurs. Not enough information was available to determine the contribution of drugs and/or alcohol to dump-point accidents.

Table 6.–Dump-point accidents involving a haulage truck, by years of mine experience

Experience	*Accidents*	*Experience*	*Accidents*
0	4	20	0
<1	13	21	1
1	8	22	0
2	8	23	1
3	7	24	0
4	3	25	1
5	4	26	1
6	3	27	1
7	2	28	0
8	3	29	0
9	3	30	0
10	5	31	0
11	3	32	0
12	1	33	0
13	1	34	0
14	1	35	1
15	3	36	0
16	1	37	0
17	1	38	0
18	1	39	1
19	0	Total	82

Seatbelt Use

In a rollover accident, seatbelts can be instrumental in the prevention of serious injury or death. The 82 haulage truck accidents were reviewed to determine if seatbelts or the lack of seatbelts were a contributing factor to the amount of injury sustained by the operator. Only 14 accident reports mentioned the use or non-use of seatbelts (table 7). Because of the lack of reporting concerning seatbelts, it is not possible to discern if the majority of lost-work-time injuries could have been reduced in severity or eliminated by the use of seatbelts. In four of seven total fatalities, however, specific mention was made that the operator was not wearing a seatbelt. A reasonable assumption can be made that at least some of the fatalities could have been prevented had seatbelts been worn. The importance of wearing seatbelts should be emphasized to all mobile equipment operators. Federal regulations currently mandate that seatbelts be provided and worn in haulage trucks (30 CFR 56.14131 and 30 CFR 57.14131).

Table 7.–Summary of data corresponding to use of seatbelts

Accidents involving–	Seatbelts–	
	Worn	Not worn
Fatalities	0	4
Permanent disability	0	1
Lost workdays	2	5
No time lost	1	0
Unknown	0	1

PRIMARY ACCIDENT CAUSES

The 26 full investigative reports provided a complete explanation of the primary accident causes and contributing factors. After a thorough review of these reports, it became evident that a relatively small group of causes were responsible for the majority of the accidents. Often there were several causes that when combined resulted in the occurrence of a dump-point accident. A pattern of several factors combining to cause a dump-point accident emerged.

For the remaining 56 accidents, where a full investigative report was not available, the one-page 7000-1 form accident reports were analyzed. Twenty-three of these reports provided enough information to determine the primary accident cause, however, the contributing factors often could not be determined. The remaining 33 reports did not provide enough detail to determine accurately the primary cause for the accident although in some cases contributing factors could be identified.

A summary of the primary accident causes is shown in figure 7. The majority of the accidents occurred as a result of administrative or operator error (loading out at the toe, backing over edge, etc.) while only eight of the accidents occurred because of an unexplained slope failure. This highlights the importance of addressing dump-point accidents from an administrative and operational viewpoint as well as the study of specific parameters effecting slope stability.

Table 8 provides a breakdown of those factors that contributed to the occurrence of an accident. The nine contributing factors identified through analysis of the accident reports are listed, along with the number of times a specific factor could be identified as contributing to the primary accident cause. Several of the contributing factors (i.e., dumpbed position, truck motion, truck orientation) provide information that can aid in modeling of the accidents.

The information in table 8 is not complete and does not provide a thorough representation of the contributing factors for all of the primary accident causes listed. Again, this is because of the lack of detail provided on many of the accident reports. It does, however, present the best information that is available and does help in development of an understanding of dump-point accidents.

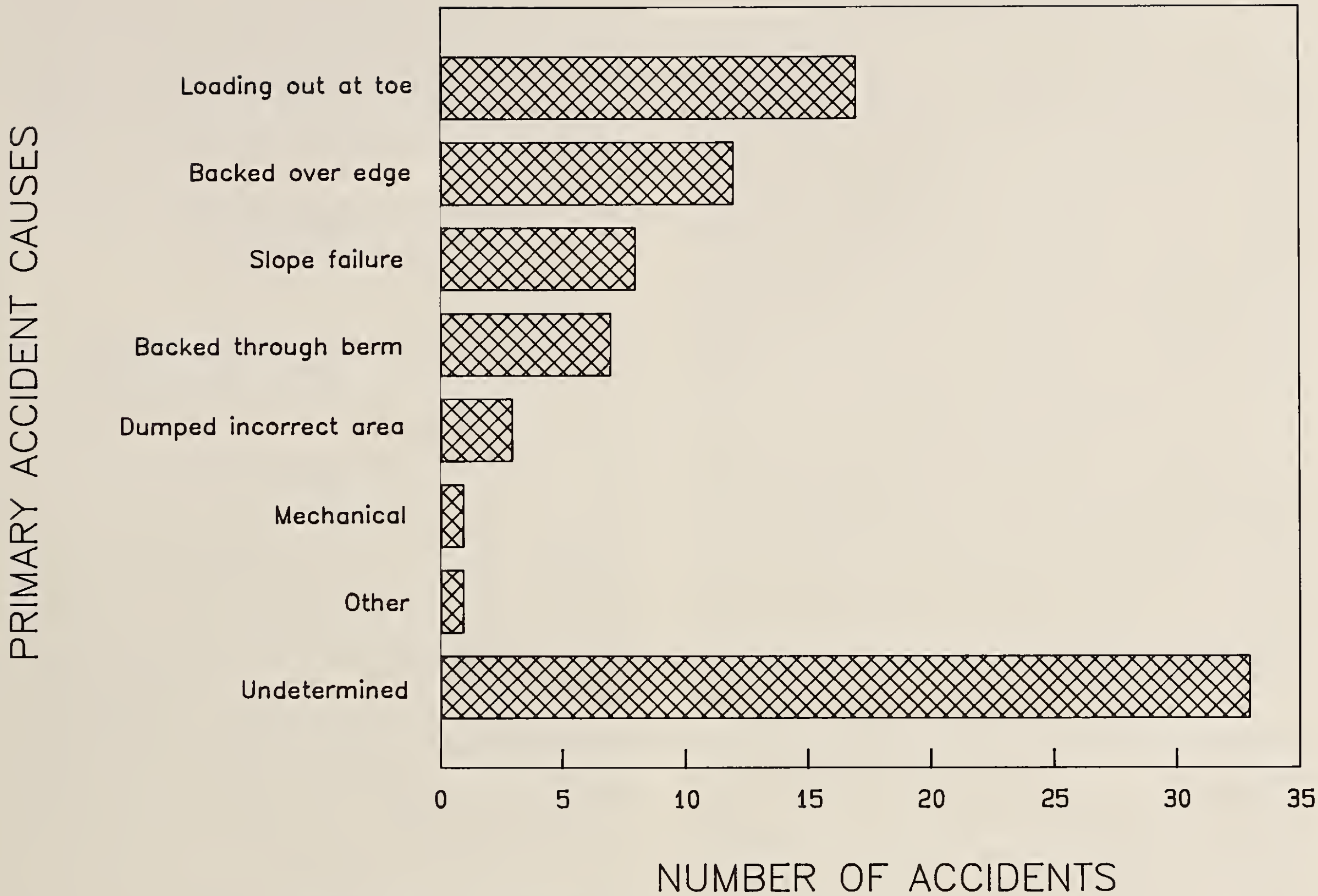

Figure 7.–Primary dump-point accident causes involving haulage trucks.

Table 8.–Primary accident causes and contributing factors for 82 dump-point accidents

Contributing factors	Loading out at the toe	Backing over edge	Slope failure	Backing through berm	Dumping incorrect area	Mechanical	Other	Undetermined	Total
Accidents[1]	17	12	8	7	3	1	1	33	82
No berm	13	11	0	0	2	1	1	2	30
Truck orientation:									
Right	0	4	3	1	2	0	0	3	13
Left	1	1	1	0	0	0	0	1	4
Substance abuse	1	1	0	0	1	0	0	0	3
No lighting	1	1	0	1	0	0	0	0	3
Dumpbed position:									
Up	2	0	2	0	0	0	0	5	9
Down	14	6	5	6	1	0	1	10	43
Slope failure	13	1	8	1	1	0	0	24	48
Truck motion:									
Moving	12	12	0	7	2	0	1	9	43
Stopped	5	0	6	0	0	0	0	5	16
Dumping incorrect area	1	0	0	0	3	0	0	0	4
Construction method	17	12	8	7	3	1	1	33	82

[1]Total accidents by primary accident cause; remaining entries in each column are number of times another factor could be identified as a contributing cause.

Loading Out at the Toe

Loading out at the toe refers to the procedure of removing material from the base or toe of a stockpile, often with a front-end loader. This material is generally loaded into trucks for shipping or is fed directly into crushers or feeders for further processing. This is a normal procedure for most mining operations and other than placing feeders under the stockpile (often not applicable) is the only method available for reclaiming stockpiled materials. The method is safe but does result in formation of vertical or near vertical faces on the leading edge of the stockpile. The formation of a stockpile face with an angle steeper than the normal angle of repose results in a slope with a reduced bearing capacity. This normally does not present a problem to the loader operator at the base of the pile, who continually watches for collapse of the steepened face while it is being reclaimed. However, any mobile equipment or personnel at or near the crest of the stockpile are in danger of being involved in a slope failure and any resulting accidents. In addition, truck drivers and other personnel on foot at the base of the pile, for instance drivers who may be walking around behind their highway truck while it is being loaded, are in danger of being engulfed during a slope failure.

Of the 49 accidents for which a specific cause could be determined, 17 occurred when a haulage truck backed to the top edge of a pile where the toe had been removed. In 14 of these accidents, the weight of the truck caused the oversteepened slope to fail with the resultant falling of the truck over the edge. In three other accidents, undercutting of the pile resulted in removal of the berm at the top of the pile. In these three instances, the truck operator simply backed over the edge of the pile.

The problem associated with dumping over the edge of a pile while concurrently loading out at the toe predominantly exists in the metal-nonmetal industry. Fifteen of the seventeen accidents occurred in the metal-nonmetal industry, seven on crushed and sized stone stockpiles, seven on quarry rock stockpiled for crusher feed, and one on an unknown stockpile. The two accidents that occurred in coal both involved overburden, one occurred when a berm had been removed because of reclamation activities on a spoil pile. Significantly, four of the seven haulage-truck-related dump-point fatalities involved an accident where the toe of a stockpile had been removed, three occurring in metal-nonmetal and one in coal.

Thirteen of seventeen accidents occurred where no berm was in place. This is important in that it could allow a truck to dump very close to the edge of an already weakened slope thereby substantially increasing the probability of a slope failure. Use of berms, however, would not adequately insure the prevention of this type of accident. In four of the accidents, berms were in place and being utilized. In these four cases the undercutting that took place resulted in slopes so weakened that the slopes including berms failed when the truck backed into place. The use of berms in these instances actually resulted in a false sense of security for the operator who assumed the berm signified a stable slope.

A method of stockpiling that concurrently utilizes end-dumping techniques while reclaiming from the toe is inherently dangerous and should be avoided. The mine supervisor should insure that these two activities do not occur concurrently at the same location, and the truck operator should insure that he or she is not dumping at a point that has been steepened by reclaiming activities.

Backing Over Edge

Backing over the edge of a pile (no slope failure) was responsible for 12 of the dump-point accidents. In this type of accident, the truck operators do not judge the distance to the edge of the pile correctly and simply back over the edge. In each accident (except one where it was not documented), a berm or spotting device had not been provided. Thus although the operator was at fault for backing too far, had a berm or spotting device been provided, the majority of these accidents could have been prevented. The major contributing factor in this case is therefore administrative for not providing a spotting device or berm as required by law. Inadequate lighting contributed to one of the accidents when the operator could not clearly see the edge of the slope. It should be noted that after discussions with MSHA personnel it is felt that missing or insufficient mirrors and poor brakes also contributed in some part to these accidents, however this cannot be substantiated.

Slope Failure

Slope failure refers to any soil movement that could contribute to or be the primary cause of a dump-point accident. The range of failure mechanisms can vary from the settlement of unconsolidated material under one wheel, resulting in the truck tipping on its side, to a massive failure where a bank or slope completely collapses under the weight of a truck.

Slope failures were involved in 58 pct of the total dump-point accidents reported. A summary of the contribution of slope failures to dump-point accidents is provided in table 9. In 25 of the accidents it was not possible to determine the type or size of the failure, or if the failure was the primary cause for the accident or only a contributing factor. A slope failure was identified as a contributing factor in the occurrence of 15 accidents and was the primary accident cause for 8 accidents.

Of the eight accidents in which a slope failure was the primary accident cause, only one was substantiated by a full investigative report. In this case, uncompacted sand sloughed away under the rear wheels of the truck causing it to turn on its side. In the remaining seven accidents the documentation was relatively poor, which prevented a thorough characterization of the failure, however, they all occurred in the coal industry. All seven of these accidents occurred on dump or fill structures where loading out at

the toe would not normally occur. This would tend to substantiate the occurrence of the slope failure due to weak geomechanical properties other than to other primary accident causes. Of these seven accidents, four occurred on spoil piles consisting of overburden, two occurred on unknown materials, and one occurred on a rock dump.

Table 9.–Summary of haulage truck dump-point accidents involving slope failure

Primary cause	*Accidents*
Loading out at the toe	13
Backed through berm	1
Dumped incorrect area	1
Undetermined	25
Slope failure	8

Backing Through Berm

Seven of the dump-point accidents occurred when the vehicle operator backed through, or in one case over, an existing berm. There is confusion as to the utilization of berms in the prevention of dump-point accidents. A normal rule of thumb states that berm height should be equal to the mid-axle height of the largest vehicle using the dump site (for haulroads this is mandatory under 56.9300 and 57.9300). But what is the purpose of a berm at a dump point? To provide a visual indication of where the truck should be stopped? To provide a "feeling" of the berm as the rear tires contact it? To impede the motion of a truck that contacts it at some moderate speed? Surely, the true purpose probably lies somewhere in between, however, the equipment operator cannot assume that a berm will impede vehicle motion or that it should be used as an aid in stopping the vehicle. A vehicle operator should utilize a berm for spotting only. Had this been done in these seven cases, most of the accidents could have been avoided.

Lack of adequate lighting contributed to the occurrence of one accident by not allowing the operator to spot the berm and thus slow in time. One of the accidents occurred when an apparently insufficient berm failed along with part of the slope when the truck contacted it (the speed of the vehicle when it contacted the berm is unknown). The relative strength of berms is dependent on their size, shape, construction materials, and type of structure on which they are located. This information has been determined for haulroads,[3] and where possible should be applied to dump points.

[3]Stecklein, G. L., and J. Labra. Haulroad Berm and Guardrail Design Study and Demonstration. Volume I (contract H0282028, SW Res. Inst.). BuMines OFR 188-82, 1981, 186 pp.; NTIS PB 83-137091.

Dumping Incorrect Area

Three of the dump-point accidents occurred when the haulage truck operator failed to dump where specified by supervisors. In two of these accidents, the operators backed over the edge of a pile where no berms were provided. In both cases, the operators had been instructed to dump in nearby areas where bulldozers were being used to push the material over the edge of the pile. It is uncertain why the operators failed to dump where instructed, although it was alluded in the reports that they may have been trying to assist the dozer operators by dumping directly over the edge. In one of these instances the operator had worked two 8-hour shifts with only 8 hours off between shifts. In this case, a fatality occurred and the autopsy revealed that the operator was legally drunk.

The third case involved an operator dumping near the middle of the pile instead of the end where directed. The operator was backing near the edge of the pile when the right rear tire began sinking in the material causing the truck to tip on its side. Although closer supervision may have prevented these accidents, the primary responsibility cases belongs to the operators.

Mechanical

A mechanical failure was responsible for only one dump-point accident. In this particular case, the parking brakes failed to hold while the operator was raising the dumpbed. This allowed the truck to roll over the edge of the dump point where no berm had been provided. In this case a berm probably would have prevented the accident. Although mechanical failures are common causes of powered haulage accidents, it cannot be shown that they are a frequent factor in dump-point accidents.

Undetermined

For 40 pct of the dump-point accidents analyzed, it was not possible to determine the primary accident cause. The accident descriptions provided by the mine operators in these cases were poorly written and often consisted of only one fragmented sentence. It could be reasonably assumed that these accidents would distribute evenly as a ratio to the known accident causes. However, in order to maintain a high degree of integrity and accuracy in this study, no attempt was made to interpret these reports or distribute them by ratio into other accident categories.

As shown in table 8, however, although the primary accident cause could not be determined it was often possible to identify contributing factors. The most significant contributing factor alluded in the reports was that some sort of slope failure occurred, although the lack of detailed descriptions precluded the characterization of the failures.

It is unclear whether the problem of inadequate and poorly written reports can be addressed and corrected by MSHA, however, such reports present problems to anyone trying to complete a detailed analysis of safety problems and health trends in the mining industry.

CONTRIBUTING FACTORS

Construction Method

In every dump-point accident analyzed, the method of stockpile construction consisted of end dumping, where the haulage truck actually dumped the load directly over the crest of the pile. Elimination of this type of dumping procedure would effectively eliminate the majority of dump-point accidents. A preferred procedure would consist of the haulage truck dumping the load back from the crest of the pile where it would then be pushed over the edge by dozer or loader. This procedure would also allow for maintenance of berms in the dump areas. It is understood that this is not always a practical alternative for a mine operator in which case other precautions should be taken when utilizing end-dumping techniques. These would include maintaining adequate berms, not loading out at the toe where stockpiling activities are going to take place, maintaining a well-trained and informed workforce, and performing regular inspections of dump points for any potential hazards or unsafe working procedures.

Truck Orientation

In 17 accidents, truck orientation was specifically mentioned as a contributing factor. In this type of accident, the truck is not backed perpendicular to the slope edge, allowing one tire to reach the edge before the other. Most often this occurs on the side of the truck opposite the driver's compartment. This apparently occurs as a result of the operator's inability to accurately judge distance on this far side. Backing at an angle to the slope edge contributed to 5 of the 12 backover accidents. In these accidents, no berms were provided and the operator's inability to judge the distances correctly allowed one tire to slip off the edge resulting in the fall of the remainder of the truck. Another potential hazard associated with backing at an angle is the uneven weight distribution imposed on the slope edge while the load is being dumped. If through misjudgment of distance the operator does not slow sufficiently before one tire contacts a berm, failure of the berm could occur, resulting in the backing of the truck over the edge.

Dumpbed Position

The position of the dumpbed could have an effect on slope stability. As the dumpbed is raised into the dumping position, the weight distribution is increased on the rear wheels resulting in increased bearing pressure on the slope. This can be magnified if the operator rocks the bed to free sticky material. Information on the position of the dumpbed could be determined in 38 accidents. In 29 accidents, the dumpbed was in the down position and in 9 it was raising or in the up position. Because of poor documentation, it was not readily apparent if the bed being in the raised position had an influence on the occurrence of slope failures.

Truck Motion

It was possible to infer the motion of the haulage truck in 59 of the dump-point accidents. In 73 pct of these accidents, the truck was in motion and moving backwards toward the slope edge. This is of particular interest in those accidents involving some degree of slope failure. As the truck applies its brakes to stop near the dump point, a horizontal force is imposed on the slope in addition to the normal vertical force imposed by the weight of the truck. This additional horizontal force substantially increases the potential of a slope failure. The result of horizontal force loadings on dump points is being carefully analyzed in modeling studies of slope failures.

ANALYSIS OF DUMP-POINT ACCIDENTS INVOLVING FRONT-END LOADERS

Front-end loaders were responsible for 5.7 pct of all dump-point accidents analyzed. This equates to six accidents for the 5-year period studied. Of these six accidents, two resulted in a fatality. A summary of front-end loader accidents by specific commodity and severity is shown in table 10. All of the accidents occurred in the aggregate industry, where front-end loaders are used heavily in the construction of stockpiles. A full investigative report (portions missing) was available for one of the accidents involving a fatality, the remaining five accidents were analyzed utilizing ADA accident narratives generated from the one-page, 7000-1 form accident reports.

Both fatalities occurred when the operator was thrown from the loader and pinned under the machine. In one instance, an equipment fall occurred as a result of the operation of the loader near the crest of a slope that had been weakened by loading out at the toe. In the other fatality, a slope failure occurred as the operator backed the right rear tire over the edge of the pile. In this accident the shape of the slope could not be determined.

For the four nonfatal accidents, the primary accident cause could not be determined, although some contributing factors could be identified including lack of berms, slope failure, and operator error (backing over edge). It appears that front-end loader accidents are similar in nature and cause to haulage truck accidents and could be reduced by techniques implemented to reduce haulage truck accidents. Front-end loaders differ from haulage trucks in that they are used for the construction of berms at the crest of stockpiles as well as for hauling material for stockpile

construction. They can spend considerably more time near the crest of a stockpile and in potentially more hazardous positions. It is therefore important that the operator remain attentive to potential hazards especially during the construction of berms and not become complacent with the work environment.

Table 10.–Summary of occurrence and severity of dump-point accidents involving front-end loaders

Industry	Accidents	Fatalities	Lost-workday accidents	Lost workdays
Sand and gravel	4	2	1	15
Crushed limestone	1	0	0	0
Crushed granite	1	0	0	0

ANALYSIS OF DUMP-POINT ACCIDENTS INVOLVING DOZERS

Dozers were responsible for 10.5 pct of all dump-point accidents. This equates to 11 accidents for the 5-year period studied. Of these 11 accidents, 2 resulted in a fatality. A summary of dozer accidents by specific commodity and severity is given in table 11. The coal industry had both the greatest frequency and severity of dump-point-related dozer accidents. The reason for the concentration of accidents within the coal industry is uncertain, although it seems reasonable that with the amount of overburden removal and reclamation activities prevalent in coal that simply more dozers are used.

ADA accident narratives were used in the analysis of all the dozer accidents, including both fatalities. Although detail in the ADA narratives is lacking, dozer accidents appear to fall into two general categories. The first category involves the operator backing the dozer over the edge of the pile either through inattentiveness or the result of mechanical problems. The second category involves a slope failure although it is not apparent if there may have been other contributing factors such as loading out at the toe.

Five accidents occurred when the dozer simply went over the edge of the pile. In one case, the throttle stuck and forced the dozer over the bank. In another, the operator momentarily lost control and the machine rolled back over a dump. In three accidents, the operators simply backed over the edge, in one case overturning the dozer and in the other two simply jarring the operator's back.

Slope failures occurred in five of the dozer accidents including one of the fatalities. In this fatality, material collapsed during a reclamation operation allowing the dozer to slide into 15 ft of water. It is unclear in this accident if the dozer was operating at the top of the pile or along the front slope. In the remaining slope-failure-related accidents, it appears that the stockpiled material collapsed under the weight of the dozer while the unit was close to and running parallel to the top edge of the pile. There is not enough information available to accurately characterize these slope failures or determine what could have been done to prevent them. The primary cause for the second dozer fatality is unclear, it was simply stated in the accident narrative that the dozer fell into a void on a coal stockpile, probably formed by a pan feeder beneath the pile.

Only four of the accidents resulted in the dozer overturning. In the others, it appears they simply slid uncontrolled for some unknown distance. Dozers operate both at the crest of structures and often on the slopes of a structure. Because of this varied usage and the poor documentation of the accidents, it is difficult to determine specific operating techniques that might eliminate the occurrence of dozer-related slope failures.

Table 11.–Summary of occurrence and severity of dump-point accidents involving dozers

Industry	Accidents	Fatalities	Lost-workday accidents	Lost workdays
Coal	6	2	4	106
Iron	1	0	1	3
Silver	1	0	1	16
Sand and gravel	1	0	1	15
Crushed limestone	1	0	0	0
Clay	1	0	0	0

ANALYSIS OF DUMP-POINT ACCIDENTS INVOLVING SCRAPERS

Only four (slightly more than 1 pct) of all scraper accidents occurred because of the fall of the scraper over a dump-point structure. None of the scraper accidents involving dump points resulted in a fatality although the number of lost workdays per LWA was extremely high, an average of 128 days per accident.

The documentation for these accidents was poor with no full investigative reports available. Two of the accidents occurred in the coal industry on spoil piles. In both instances, it appears the unit was dumping near the edge of the stockpile when it slid over the edge. The remaining two accidents occurred in the crushed limestone industry. The stockpile material for these accidents was not listed, however, as in coal, most scraper operations involve the movement of overburden. In both of the limestone industry accidents it was stated that the scraper was driven too close to the edge of the pile. It is unclear in these cases whether a slope failure occurred or if the operator simply drove over the edge.

MSHA REGULATIONS PERTAINING TO DUMP-POINT SAFETY

MSHA has the responsibility for the development and enforcement of Federal regulations relating to the promotion of safety and health and the prevention of accidents in the metal-nonmetal and coal industries. The generation and development of most safety-related regulations takes place over time in response to specific hazards occurring in the minerals industry. The regulations in effect are the accumulation of many years of effort and evolution by MSHA to reduce the severity and frequency of mining accidents. These regulations continue to evolve and change to reflect changing mining methods and technologies. A review of those regulations that have been generated in response to the specific hazards associated with dump points provides a more thorough understanding of dump-point accidents, the environment in which they occur, and approaches taken to control them. Regulations pertaining to the construction and use of stockpiles and dump points are included in the CFR, Title 30–Mineral Resources, parts 56, 57, and 77. Excerpts of those regulations specifically directed towards the operation of mobile mining equipment on stockpiles and waste dumps are contained in the appendix, as well as additional regulations indirectly related to equipment operation.

A review of the regulations pertaining to the construction and use of stockpiles and waste dumps highlights the difficulties encountered in regulating the minerals industry. The minerals industry is extremely diverse. Its operations vary greatly, depending upon the commodity mined and the specific mining methods and equipment used. The parameters that can vary in regard to the construction and use of stockpiles and waste dumps include the type of material used, the construction method, the pile size, the type and size of the mobile equipment, the effects of weather, the effects of reclaiming, and many others. The varying nature and complexity of the parameters affecting stockpile and waste dump construction is reflected in the generalized and somewhat vague wording that is used in the regulations. This may also reflect a basic lack of information about the parameters that affect stockpile and waste dump stability, resulting in the inability to generate more specific guidelines and regulations.

SUMMARY

Failures at mine dump points are particularly dangerous because of the height of the slopes and size of the mobile equipment involved. When slope instability or operational errors result in a piece of mobile equipment tumbling over the edge of a stock pile or waste dump the results can be disastrous. In most cases, the accidents result in lost work time or death. Approximately 16 accidents resulting in lost work time or death occur every year. Although this is a relatively small number, dump-point accidents have a much higher likelihood of resulting in a fatality or significant lost-work-time injury than most other surface mining accidents. Dump-point accidents occur in all of the major mineral industries including coal, metal, nonmetal, crushed stone, and sand and gravel; however, they predominantly occur in the crushed stone and coal industries.

After a thorough review of the 82 dump-point accidents, it became evident that a relatively small group of causes were responsible for the majority of the accidents. The accidents were primarily due to administrative or operator error (loading out at the toe, backing over edge, etc.) while only a small percentage of accidents involved unexplainable slope failures. The majority of the accidents could have been avoided had there been a better understanding of the potential hazards associated with the operation of mobile equipment on stockpiles and waste dumps and the interrelationship between vehicle operation and slope stability.

Most of the accidents involved haulage trucks although dozers, front-end loaders, and scrapers accidents also occurred. A better understanding of the potential hazards associated with stockpiles and waste dumps should allow mine operators to minimize the occurrence of this type of accident.

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APPENDIX.–CODE OF FEDERAL REGULATIONS EXCERPTS PERTAINING TO OPERATION OF MOBILE EQUIPMENT ON STOCKPILES AND WASTE DUMPS

The following excerpts of Title 30–Mineral Resources pertain to operation of mobile equipment on stockpiles and waste dumps. In addition to the excerpts, other regulations within parts 56, 57, and 77 that are indirectly related to such operation are cited. Portions of Part 48–Training and Retraining of Miners, are also included. The following regulations are subject to periodic revision. A MSHA representative should be contacted on a regular basis for changes.

SAFETY AND HEALTH STANDARDS–SURFACE METAL AND NONMETAL MINES

30 CFR 56.9101 Operating speeds and control of equipment.

Operators of self-propelled mobile equipment shall maintain control of the equipment while it is in motion. Operating speeds shall be consistent with conditions of roadways, tracks, grades, clearance, visibility, and traffic, and the type of equipment used.

30 CFR 56.9301 Dump site restraints.

Berms, bumper blocks, safety hooks, or similar impeding devices shall be provided at dumping locations where there is a hazard of overtravel or overturning.

30 CFR 56.9303 Construction of ramps and dumping facilities.

Ramps and dumping facilities shall be designed and constructed of materials capable of supporting the loads to which they will be subjected. The ramps and dumping facilities shall provide width, clearance, and headroom to safely accommodate the mobile equipment using the facilities.

30 CFR 56.9304 Unstable ground.

(a) Dumping locations shall be visually inspected prior to work commencing and as ground conditions warrant.

(b) Where there is evidence that the ground at a dumping location may fail to support the mobile equipment, loads shall be dumped a safe distance back from the edge of the unstable area of the bank.

30 CFR 56.9305 Truck spotters.

(a) If truck spotters are used, they shall be in the clear while trucks are backing into dumping position or dumping.

(b) Spotters shall use signal lights to direct trucks where visibility is limited.

(c) When a truck operator cannot clearly recognize the spotter's signals, the truck shall be stopped.

30 CFR 56.9314 Trimming stockpile and muckpile faces.

Stockpile and muckpile faces shall be trimmed to prevent hazards to persons.

The following are regulations of part 56 that indirectly relate to stockpile construction and use, and regulations pertaining to aspects of stockpile construction not involving the use of mobile mining equipment.

30 CFR 56.3130	Wall, bank, and slope stability
30 CFR 56.3200	Correction of hazardous conditions
30 CFR 56.3401	Examination of ground conditions
30 CFR 56.14100	Safety defects, examination, correction and records
30 CFR 56.14130	Rollover protective structures and seat belts
30 CFR 56.14131	Seat belts for haulage trucks
30 CFR 56.17001	Illumination of surface working areas
30 CFR 56.20001	Intoxicating beverages and narcotics

SAFETY AND HEALTH STANDARDS–UNDERGROUND METAL AND NONMETAL MINES

Regulations for surface stockpiles and waste dumps at underground metal and nonmetal mining locations (30 CFR 57) are identical to those in 30 CFR 56 for surface mines.

MANDATORY SAFETY STANDARDS, SURFACE COAL MINES AND SURFACE WORK AREAS OF UNDERGROUND COAL MINES

30 CFR 77.1605 Loading and haulage equipment; installations.

(i) Ramps and dumps shall be of solid construction of ample width, have ample clearance and headroom, and be kept reasonably free of spillage.

(l) Berms, bumper blocks, safety hooks, or similar means shall be provided to prevent overtravel and overturning at dumping locations.

30 CFR 77.1607 Loading and haulage equipment; operation.

(b) Mobile equipment operators shall have full control of the equipment while it is in motion.

30 CFR 77.1608 Dumping facilities.

(a) Dumping locations and haulage roads shall be kept reasonably free of water, debris, and spillage.

(b) Where the ground at a dumping place may fail to support the weight of a loaded dump truck, trucks shall be dumped a safe distance back from the edge of the bank.

(c) Adequate protection shall be provided at dumping locations where persons may be endangered by falling material.

(d) Grizzlies, grates, and other sizing devices at dump and transfer points shall be anchored securely in place.

(e) If truck spotters are used, they shall be well in the clear while trucks are backing into dumping position and dumping; lights shall be used at night to direct trucks.

The following are regulations of part 77 that indirectly relate to stockpile construction and use, and regulations pertaining to aspects of stockpile construction not involving the use of mobile mining equipment.

30 CFR 77.209	Surge and storage piles
30 CFR 77.214	Refuse piles; general
30 CFR 77.215	Refuse piles; construction requirements; identification; reporting requirements; certification; abandonment
30 CFR 77.403a	Mobile equipment; rollover protective structures
30 CFR 77.404	Machinery and equipment; operation and maintenance
30 CFR 77.1000	Highwalls, pits and spoil banks, plans
30 CFR 77.1600	Loading and haulage; general
30 CFR 77.1606	Loading and haulage equipment; inspection and maintenance

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